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The Sting of Rejection: Deferring Blood Donors due to Low Hemoglobin Values Reduces Future Returns

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Abstract: Background: Roughly one quarter of short-term temporary deferrals (STTD) of blood donors are low-hemoglobin deferrals (LHD), i.e. STTD due to a hemoglobin (Hb) value falling below a cutoff of 125 g/L for female and 135 g/L for male donors. Since voluntarily donating blood is a prosocial activity, donors may perceive deferral as social exclusion, which can cause social pain, decrease self-esteem, and lead to antisocial behavior. However, little is known about the causal impacts of LHD on donor return. Study Design and Methods: We conducted a quasi-experiment with 80,060 donors invited to blood drives in the canton of Zurich, Switzerland, between 2009 and 2014. Within a narrow window of Hb values around the predetermined cutoff, the rate of LHD jumps discontinuously. This discontinuous jump allows us to quantify the causal effects of LHD on donor return, as it is uncorrelated with other unobserved factors that may also affect donor return. Results: We found different behavioral reactions to LHD for female and male donors. Female donors do not react to the first LHD. However, after any repeated LHD, they are 13.53 percentage points ($p < 0.001$) less likely to make at least 1 donation attempt within the next 18 months and make 0.389 fewer donation attempts ($p < 0.001$). Male donors react to the first LHD. They are 5.32 percentage points ($p = 0.139$) less likely to make at least 1 donation attempt over the next 18 months and make 0.227 ($p = 0.018$) fewer donation attempts. After any repeated LHD, male donors are 13.30 percentage points ($p = 0.004$) less likely to make at least 1 donation attempt and make 0.152 ($p = 0.308$) fewer donation attempts. Conclusion: LHD have detrimental impacts on donor return, especially if they occur repeatedly – suggesting that avoiding false LHD and helping donors to better cope with them helps to maintain the pool of prospective donors.

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The Sting of Rejection: Deferring Blood Donors due to Low Hemoglobin Values Reduces Future Return

Research Paper

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Abstract

BACKGROUND: Roughly one quarter of short-term temporary deferrals (STTDs) of blood donors are low hemoglobin deferrals (LHDs), i.e. STTDs due to a hemoglobin (Hb) value falling below a cutoff of 125g/L for female and 135g/L for male donors. Since voluntarily donating blood is a prosocial activity, donors may perceive deferrals as social exclusion, which can cause social pain, decrease self-esteem, and lead to anti-social behavior. Yet, little is known about the causal impacts of LHDs on donor return.

STUDY DESIGN AND METHODS: We use a quasi-experiment with 80,060 donors, invited to blood drives in the canton of Zurich, Switzerland between 2009 and 2014. Within a narrow window of Hb values around the predetermined cutoff, the rate of LHDs jumps discontinuously. This discontinuous jump allows us to quantify the causal effect of LHDs on donor return, as it is uncorrelated with other unobserved factors that may affect donor return too.

RESULTS: We find different behavioral reactions to LHDs for female and male donors. Female donors do not react to the first LHD. However, after any repeated LHD, they are 13.53 percentage points (p-value < 0.001) less likely to make at least one donation attempt within the next 18 months and make 0.389 fewer donation attempts (p-value < 0.001). Male donors already react to the first LHD. They are 5.32 percentage points (p-value: 0.139) less likely to make at least one donation attempt over the next 18 months and make 0.227 (p-value: 0.018) fewer donation attempts. After any repeated LHD, male donors are 13.30 percentage points (p-value: 0.004) less likely to make at least one donation attempt and make 0.152 (p-value: 0.308) fewer donation attempts.

CONCLUSION: LHDs have detrimental impacts on donor return, especially if they occur repeatedly – suggesting that avoiding false LHDs and helping donors to better cope with them helps to maintain the pool of prospective donors.

Keywords

Blood donation, donor deferral, donor return, quasi-experiment

Introduction

A substantial fraction (9.75%) of blood donation attempts are deferred due to strict donation criteria. One major criterion, accounting for almost a quarter of all deferrals, is an on-the-spot-measurement of the Hb value which triggers a LHD when it falls below a predefined cutoff. The cutoff is nationally defined to safeguard the health of recipients of transfusion and the blood donors themselves. About 2-12% of all blood donors display insufficient Hb values (1-3). Moreover, measurement error leads to false LHDs where the donors' true Hb value is above the cutoff (4). While most studies on donor return focused on the effects of material incentives (5-8), and on correlations with donor characteristics (9), little is known about the causal impact of LHDs on donor return.

Donors may take LHDs as an excuse to refrain from donating blood in the future. In line with the literature about excuse-driven behavior (10-11), donors who experienced a LHD may believe that getting deferred again is likely and, thus, refrain from future donation attempts. Furthermore, donors may perceive LHDs as social exclusion. Studies on other types of prosocial activities suggest that social exclusion can cause social pain and decrease self-esteem, even if it is only implicit and due to exogenous circumstances rather than the behavior of others (12-15).

The way in which individuals respond to social exclusion is ambiguous. On the one hand, individuals may respond to exclusion in socially desirable ways to satisfy their need for belongingness, but on the other hand, they may also exhibit anti-social reactions in case they have no control over the cause of their exclusion (16). As donors cannot control their Hb values at a given point of time, we hypothesize that deferred donors may refrain from future donation attempts or, at least, reduce their donation frequency. A study looking at the effect of various STTDs by comparing donation rates of donors computer-matched based on age, gender and donation date supports this hypothesis. It found that donors who experienced a LHD were 13.6% less likely to return over the next 4.25 years than non-deferred donors (17). More recent studies also reported negative correlations between STTDs and future donation attempts (18-21). However, deferred and non-deferred donors may differ, for example in terms of their health status, which may also affect donor return. This makes the interpretation of these correlational results and, in particular, their magnitudes difficult. We provide a novel causal analysis that identifies the local average treatment effect of LHD on donor return, among otherwise identical marginal donors.

Repeated LHDs might even have a stronger detrimental effect on donor return. Prior evidence shows that repeated social exclusion can lead to maladaptive responses causing further deferrals (22) and depression (23). Since we only observe donation attempts in a given period, we differentiate between the first LHD and repeated LHDs during our study period. We quantify the causal effect of LHDs on donor return both overall and for repeated LHDs.

Materials and Methods

Empirical Setup

Our sample comprises 80,060 voluntary blood donors who donated at least once before the study. They were repeatedly invited to blood drives organized by the Blood Transfusion Service of the Red Cross in Zurich, Switzerland (BTSRC). Blood drives typically take place twice a year at the same location.

We observe 260,026 donation attempts during the sample period from January 2009 to November 2014. For each donation attempt, we also observe the donors' gender, age, blood type, recorded Hb value and whether the donation attempt failed due to a LHD or some other reason. The term "donation attempt" refers to both successful and failed donations, as failed donations equally show the willingness to donate. Our data set comprises no further information.

The BTSRC applies different cutoffs of the Hb values for female (≥125g/L) and male (≥135g/L) donors and may give gender-specific feedbacks in response to LHDs. Therefore, we analyze female and male donors separately.

42.9% of donors are female, accounting for 39.1% of all donation attempts (see Table S1 in the Supporting Information for detailed descriptive statistics). On average, female donors are 39.73 (±14.00 SD) years old, while male donors are 42.65 (±13.82 SD) years old. The average Hb value is 137.71g/L (±10.47 SD) for female and 153.21g/L (±11.17 SD) for male donors.

LHDs

In total, 12.4% and 8.1% of donation attempts by female and male donors, respectively, are deferred for any reasons. About 4.7% of the donation attempts by female donors (38% of all deferrals) and 1.2% by male donors (15% of all deferrals) result in LHDs. Female donors are more likely to experience LHDs, as their cutoff is stricter relative to their baseline Hb values and their Hb values tend to vary more due to the menstruation cycle. LHDs can occur repeatedly. 1.3% of female donors and 0.4% of male donors experienced more than one LHD.

There is substantial error in the measurement of Hb values, mainly due to the imprecise mobile measurement devices (1, 4, 24). To avoid false LHDs, the BTSRC applies the procedure illustrated in Figure 1 for recording Hb values. When the first measured Hb value is above the cutoff, the staff records it and clears the individual for donation. However, when the first measurement falls below the cutoff, the staff repeats the measurement two more times and records the average value of all three measurements. Only if the final two measurements are both above the cutoff, the staff clears the individual for donation.

Table 1 presents possible scenarios that may arise under this procedure. For instance, a recorded Hb value of 124g/L for a female donor may lead to opposite outcomes. In scenario a), an insufficient Hb value is followed by two sufficient Hb values, resulting in a successful donation attempt. In scenario b), an insufficient Hb value is followed by one sufficient and one insufficient Hb value, resulting in a LHD. Similarly, when we observe a recorded Hb value of 125g/L, it can either be the first and only measurement, directly leading to a successful donation; or it can be the average of three measurements, of which two are insufficient, leading to a LHD.

The procedure has two consequences. First, it introduces noise around the cutoff which makes the recorded Hb value a fuzzy, i.e., probabilistic, indicator for LHDs. Second, as visualized in Figure 2, it results in a distorted normal distribution of the recorded Hb values at the cutoff because Hb values just below the cutoff are revised more often. However, since this distortion originates directly from the BTSRC's procedure and not from the donors' behavior, it is uncorrelated with donor return. Hence, given that the donors cannot manipulate their Hb values at a given point of time, LHDs around the cutoff are exogenous to donor return.

In case of a LHD, the BTSRC communicates the temporary nature of the shortfall in the Hb value and recommends the donor to wait three months before making the next donation attempt. This corresponds to the waiting-period after a successful donation.

Donor Return

We define donor return in two ways: i) as an indicator whether a donor makes at least one donation attempt within the next 18 months after the last donation attempt, and ii) as the number of donation attempts within the next 18 months after the last donation attempt. The first measure indicates whether the donors stay in the pool at all after experiencing a single or repeated LHDs. The second measure tells us how they adjust their donation frequency after a single or repeated LHDs. We use the last 18 months of our data set exclusively to construct the donor return measures, because for any potential LHD during this period, there is not enough time to observe the donors' future donation attempts. The resulting sample size is 29,371 female donors with 77,170 donation attempts and 40,145 male donors with 119,658 donation attempts.

65.5% (± 47.5 SD) of female donors and 71.7 % (± 45.0 SD) of male donors made at least one donation attempt within the next 18 months. On average, female donors made 1.200 (±1.133 SD) and male donors made 1.442 (±1.222 SD) donation attempts within the next 18 months.

Quantifying Causal Effects of LHDs on Donor Return

We use a regression-discontinuity (RD) design to quantify the causal effects of LHDs on donor return (25). The RD design exploits that the BTSRC follows the cutoff in HB values for accepting or deferring donors. It compares the return of donors whose Hb values are just above and just below the cutoff within a narrow window of -10 and +30 g/L Hb around the cutoff. (Results based on an alternative, symmetric window of -10 and +10 g/L Hb around the cutoff can be found in Section A.6 in the Supporting Information.)

Within this narrow window, donors above and below the cutoff differ only slightly in their Hb values. Thus, any unobserved factors related to both the Hb values and the donors' return – such as certain deceases – are comparable for donors with Hb values just above and below the cutoff. Yet, the probability of experiencing a LHD jumps discontinuously at the cutoff: donors with Hb values just below the cutoff are deferred much more frequently than those with Hb values just above the cutoff. Consequently, any difference in their return is due to the discontinuous jump in the probability of experiencing a LHD.

Figure 3 illustrates that the rate of donors experiencing a LHD in fact jumps discontinuously at the cutoff. Both female (Panel a) and male (Panel b) donors do not experience any LHDs when their Hb value is above the cutoff. However, once their Hb value falls below the cutoff, the rate of LHDs increases discontinuously. At the same time, as can be seen in Section A.5 in the Supporting Information, none of the donors' other observable characteristics except having the blood type O-, which is in especially high demand and may be subject to different regulation, jumps at the cutoff. This confirms that donors with Hb values just below and above the cutoff differ exclusively in the probability of experiencing LHDs.

However, not all donors with an Hb value below the cutoff experience LHDs. Figure 3 reveals that the rate of LHDs is about 80% for female and 75% for male donors whose Hb value is just slightly below the cutoff. This follows from the procedure the BTSRC applies for mitigating false LHDs, which implies that some donors with recorded Hb values slightly below the cutoff can still donate (see Figure 1 and Table 1). Formally, this means that Hb values below the cutoff are fuzzy indicators of LHDs.

To take this fuzziness into account, we have to use a so-called fuzzy RD design. In the fuzzy RD design, the indicator D whether a donor's Hb value is below the cutoff serves as an instrument for quantifying the effect of LHDs on her return rate. Figure 4 illustrates the intuition. The indicator D satisfies two properties, making it a strong and valid instrument. First, D has a strong effect on the probability of experiencing a LHD, which jumps when the Hb value falls below the cutoff. Second, D is exogenous with respect to all other unobserved factors that may be related to both the probability of experiencing a LHD and the donor's return rate. This is because, within the narrow window around the cutoff, whether the Hb value is below (D=1) or above (D=0) the cutoff is unrelated to any of these other factors. To quantify the effect of a LHD on donor return in the fuzzy RD design, we have to apply an instrumental variable estimator (25). Intuitively, such an estimator proceeds in two stages. First, it estimates the difference in return rates between donors with Hb values above and below the cutoff. In the second stage, it takes into account the indicator D's fuzziness, and scales up the difference in donor return by the predicted difference in the rate of LHDs. As an illustration, consider for example male donors. As can been seen in Panel B of Figure 5, male donors with Hb values just below the cutoff make roughly 1.57-1.40 = 0.17 fewer donation attempts within the next 18 months than their peers with Hb values just above the cutoff. Thus, in the first stage, the estimated difference in donor return is -0.17. However, Figure 3 shows that only about 75% of male donors with an Hb value below the cutoff experience LHDs. Thus, in the second stage, the difference in donor return is scaled up to -0.17/0.75 = -0.23 to estimate by how much LHDs reduce the male donors' number of donation attempts within the next 18 months.

The instrumental variable estimator used in our empirical models is called two-stage-least-squares (2SLS). It has a similar intuition but additionally provides standard errors and allows us to include control variables to increase precision. For details, see Section A.2 in the Supporting Information.

Empirical Models

We estimate the effects of LHDs on donor return in two empirical models. The first model estimates the overall effect of LHDs, while the second distinguishes between the effects of the first vs. repeated LHDs.

In both models, we use the two definitions of donor return to specify the outcome variables. In version A of the models, the outcome variable is the probability of making at least one donation attempt within the next 18 months, while in version B, it is the number of donation attempts within the next 18 months.

The first model estimates the overall effect of LHDs with a single indicator. The second model adds an interaction term between the indicators of the current LHD and past LHDs to differentiate between the effects of the first vs. repeated LHDs. The second model also includes an indicator of past LHDs as a control variable to give the interaction term the desired interpretation.

Besides estimating the effects of LHDs on donor return, both models include control variables to increase precision. These control variables are the recorded Hb value, an interaction term between the recorded Hb value and the indicator D, as well as age specified as a third-degree polynomial. Specifying a third-degree polynomial is necessary, as we expect age to affect donor return non-linearly, in line with previous research (21). Both models also include the donors' blood types and month fixed effects to control for permanent blood-type-related and seasonal differences in the supply and demand for blood transfusions. For details about the two empirical models, see Section A.2 in the Supporting Information.

Results

This section presents descriptive evidence and the estimation results. First, it illustrates how donor return reacts to changes in the Hb value at the cutoffs. Subsequently, it reports the effects of LHDs on donor return according to the two empirical models.

Descriptive Evidence

We first show descriptive evidence for the relationship between donor return and the recorded Hb value. Panel A in Figure 5 displays how the probability of making at least one donation attempt within the next 18 months reacts to changes in the Hb value close to the cutoff. For female donors, there is hardly any difference in the probability of making at least one donation attempt when their Hb value is below vs. above the cutoff of 125g/L. For male donors, there is a small discontinuous decrease in the probability of making at least one donation attempt when their Hb value falls below the cutoff. Panel B in Figure 5 indicates how the average number of donation attempts within the next 18 months reacts to changes in the Hb value close the cutoff. As with the other measure of donor return, there is hardly any difference for female donors in the number of donation attempts when their Hb value falls below the cutoff. For male donors, however, there is a discontinuous decrease when their Hb value falls below the cutoff.

The discontinuous decrease at the cutoff indicates that LHDs negatively affect the male donors' return rate. We now quantify these effects by estimating the empirical models.

The Causal Effects of LHD on Donor Return

Table 2 shows the results of the first empirical model estimating the overall effect of LHDs on donor return. (The first stage regressions can be found in Section A.3/Table S2 in the Supporting Information.)

There is a difference between the overall reactions of female and male donors to LHDs. The female donors' return rate reacts neither in terms of the probability of making at least one donation attempt (point estimate: -0.034; p-value: 0.150) nor in terms of the number of donation attempts (point estimate: 0.009; p-value: 0.877), as both coefficients are insignificant.

In contrast, LHDs strongly affect the male donors' overall return rate. They are 6.07 percentage points (p-value: 0.095) less likely to make at least one donation attempt within the next 18 months and also make 0.221 (p-value: 0.024) fewer donation attempts within the same period. This effect nicely coincides with the crude analysis (*1.57-1.40=0.17)* described earlier in the methods section. Relating the estimated effect to the baseline number of donation attempts (cf. Table S1 in the Supporting Information) reveals that male donors make 0.221/1.442 = 15.33% donation attempts less within the next 18 months after a LHD. The difference between female and male donors is insignificant in version A (p-value: 0.578) but significant in version B (p-value: 0.067) of the model.

The Hb value itself correlates with donor return only negligibly within the considered window of [-10, 30] g/L around the cutoff, although the coefficients are significant. For female donors, a 1-unit increase in the Hb value above the cutoff is related to a decrease of 0.0931 percentage points in the probability of making at least one donation attempt (p-value <0.001) and of 0.00145 in the number of donation attempts (p-value: 0.033). Compared to Hb values above the cutoff, a 1-unit increase in the Hb value below the cutoff is related to an increase of 0.177 percentage points in the probability of making at least one donation attempt (p-value: 0.630) and of 0.0161 in the number of donation attempts (p-value: 0.058). For male donors, a 1-unit increase in the Hb value above the cutoff is related to a decrease of 0.0693 percentage points in the probability to donate at least once (p-value < 0.001) and of 0.00226 in the number of donation attempts (p-value < 0.001). Compared to Hb values above the cutoff, a 1-unit increase in the Hb value below the cutoff is related to an increase of 0.691 percentage points in the probability of making at least one donation attempt (p-value: 0.211) and of 0.0106 in the number of donation attempts (p-value: 0.476).

The estimated age polynomials indicate that the relationship between age and donor return is inversely U-shaped. In version B of the model, both female and male donors have the highest propensity to make donation attempts at the age of 60. Compared to a 60-year old female donor, a 20-year old female donor is predicted to make 0.63 fewer donation attempts, a 40-year old female donor is predicted to make 0.33 fewer donation attempts and a 70-year old female donor is predicted to make 0.19 fewer donation attempts. Compared to a 60-year old male donor, a 20-year old male donor is predicted to make 0.98 fewer donation attempts, a 40-year old male donor is predicted to make 0.25 fewer donation attempts and a 70-year old male donor is predicted to make 0.08 fewer donation attempts. Qualitatively, the relationship is identical in version A of the model.

Effects of the First vs. Repeated LHDs on Donor Return

Table 3 shows the results of the second empirical model, differentiating between the effects of the first vs. repeated LHDs. (See Section A.3/Table S3 for first stage regressions and Section A3/Figure S1 for graphical illustrations in the Supporting Information.)

When female donors experience their first LHD, their return rate is affected neither in terms of the probability of making at least one donation attempt (p-value: 0.362) nor the number of donation attempts within the next 18 months (p-value: 0.449). However, when they experience repeated LHDs, their return rate drops significantly. They are 13.53 percentage points (p-value < 0.001) less likely to make at least one donation attempt within the next 18 months after a repeated LHD compared to the first LHD. They also make 0.387 (p-value < 0.001) fewer donation attempts within the same period. Relating the estimated effect to the baseline number of donation attempts (cf. Table S1 in the Supporting Information) shows that female donors make 0.387/1.200 = 32.25% less donation attempts after repeated LHDs.

In contrast, male donors already react to the first LHD. While the probability of making at least one donation attempt within 18 months after their first LHD drops only insignificantly by 5.32 percentage points (p-value: 0.139), they make 0.227 (p-value: 0.018) fewer donation attempts over the same period. Relating this effect to the baseline number of donation attempts (cf. Table 4 in the Supporting Information) shows that male donors make 0.227/1.442 = 15.74% less donation attempts after the first LHD. The difference in the estimated coefficients between male and female donors is insignificant in version A (p-value: 0.503) but significant in version B (p-value: 0.028) of the model.

When male donors experience repeated LHDs, they are 13.30 percentage points (p-value: 0.004) less likely to make at least one donation attempt within 18 months compared to the first LHD. They also make 0.152 fewer donation attempts (p-value: 0.308) during the same period. Relating the estimated effect to the baseline number of donation attempts (cf. Table S1 in the Supporting Information) shows that male donors donate an additional 0.152/1.442 = 0.54% less after repeated LHDs. The estimated coefficients of the interaction terms do not differ significantly for female and male donors, neither in version A (p-value: 0.974) nor in version B (p-value: 0.210) of the model. The remaining coefficients have a similar effect as before and can be interpreted as in the first empirical model.

Discussion

This study estimates and quantifies the causal effects of LHDs on donor return. After a first LHD, female donor return reacts neither in terms of the probability of making a donation attempt (point estimate: -0.034; p-value: 0.150) nor in terms of the number of donation attempts (point estimate: 0.009; p-value: 0.877). In contrast, male donors are 6.07 percentage points (p-value: 0.095) less likely to make a donation attempt within the next 18 months after a first LHD and also make 0.221 (p-value: 0.024) fewer donation attempts within the same period.

However, when female donors experience repeated LHDs, their return rate drops significantly. They are 13.53 percentage points (p-value < 0.001) less likely to make a donation attempt within the next 18 months and make 0.378 (p-value <0.001) fewer donation attempts within the same period compared to the first LHD. When male donors experience repeated LHDs, they are 13.30 percentage points (p-value: 0.004) less likely to make a donation attempt within 18 months and make 0.152 fewer donation attempts (p-value: 0.308) during the same period compared to the first LHD.

In sum, male donors already react to the first LHD whereas female donors respond only after repeated LHDs. One reason for this pattern might be the fact that female donors are more likely to display a temporarily insufficient Hb values, as the rule for LHDs is stricter for female donors given their baseline Hb values and, at the same time, their Hb values fluctuate more due to the menstruation cycle. Consequently, LHDs are more common for female donors and might be communicated in a less detrimental way.

Our contribution to the previous literature on donor return is mainly two-fold. First, we apply a regression-discontinuity design which allows us to quantify the causal effects of LHDs on donor return. Previous studies have shown negative correlations between LHDs and donor return, however, to what extent these negative effects are caused by the LHDs per se rather than by unobserved factors remains unexplored. On the one hand, conditions, such as anemia, that lead to low Hb values and LHDs could prevent donors from making future donations. On the other hand, conditions that lead to high Hb values, such as smoking (26) or dehydration (27), may also obstruct donor return. Therefore, it is crucial to filter out any unobserved factors that could confound the results. The regression-discontinuity design allows us to estimate the causal effects of LHDs that are not driven by those unobserved factors. As a result, our estimates are smaller in magnitude comparing to previous studies (17-21) that omitted those unobserved factors underlying the LHDs. Second, we not only estimate the causal effects of LHDs overall but also discriminate between the causal effects of the first vs. repeated LHDs. The finding that female donors react much stronger to repeated LHDs than to the first LHD is, to our knowledge, novel as well.

More broadly, since voluntary blood donation is a textbook example of prosocial behavior, our results are in line with the economic literature on excuse-driven responses in prosocial behavior (10,11) when deferred donors use LHDs as excuses for not returning. Our results are also consistent with the psychology literature on the negative effects of social exclusion (13-16) on prosocial behavior when deferred donors perceive LHDs as social exclusion.

The results are highly policy-relevant. First of all, the results indicate that blood transfusion services should try to minimize unnecessary LHDs due to false measurement. It might be worthwhile to use more accurate measurement devices to avoid such unnecessary LHDs, even if they entail higher costs and longer measurement times.

Moreover, communicating LHDs to deferred donors should be considered a delicate matter. Transfusion services could staff additional personnel to spend more time on (i) comforting deferred donors and explaining them that insufficient Hb values are often temporary, (ii) preparing a take home message that , for example, suggests an iron- and vitamin-rich diet over the next weeks, and (iii) draft a more delicate invitation letter for those who were previously deferred.

Additionally, the BTSRC could change the uniform invitation procedure and differentiate the causes of the low Hb values. Currently, deferred donors are recommended to wait three months before making the next donation attempt. The BTSRC sends the same invitation letter after the same waiting period to deferred and nondeferred donors. While this waiting time is necessary for deferred donors with chronic iron deficiency and severe diseases, it is probably unnecessarily long for deferred donors who simply have temporary low Hb values caused by other conditions. If the BTSRC could identify and differentiate the causes of the low Hb values, it could recommend more specific waiting times and encourage deferred donors with good health conditions to return sooner.

Another solution to avoid the frustration caused by LHDs may be to allow donors with an Hb value just below the cutoff to donate nevertheless and, subsequently, discard their blood transfusions as they do not meet the required quality standards. However, the benefit of this solution would have to be carefully assessed against its cost and reputational risk.

Testing the effectiveness of the above solutions also opens up an avenue for future research. Our methodology should be applicable in such tests.

This study has some limitations. First, we only provide evidence for the effects of LHDs, but remain silent about the effects of STTDs due to other reasons. Second, our identification comes from donors with Hb values close to the cutoff. Whether the results are valid for donors with Hb values that are far away from the cutoff remains unclear. However, deferrals of donors close to the cutoff are the most relevant STTDs, as donors far above or far below the cutoff are rarely ever deferred or rarely ever eligible.

Statement of Ethics

All subjects have given their informed consent in written form. There were no animals involved. The study protocol was approved on May 27, 2016 by the institute's ethics committee on human research (Committee on Ethics in Research, HEC Lausanne, University of Lausanne).

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Tables

Table 1: Example of scenarios leading to different recorded Hb values and outcomes

	Measurement [g/L]			Recorded average Hb value [g/L]	Outcome
	1st	2nd	3rd		
a)	120	125	127	124	success
b)	124	125	123	124	LHD
c)	125	-	-	125	success
d)	124	130	121	125	LHD

Legend: All examples are for female donors with a cutoff at Hb≥125g/L. A recorded Hb value of 124g/L can originate from two different scenarios with opposite outcomes. In scenario a), an insufficient Hb value is followed by two sufficient Hb values, resulting in a successful donation attempt. In scenario b), an insufficient Hb value is followed by one sufficient and one insufficient Hb value, resulting in a LHD. Similarly, when we observe a recorded Hb value of 125g/L, it can either be the first and only measurement, directly leading to a successful donation (scenario c); or it can be the average of three measurements, of which two are insufficient, leading to a LHD (scenario d).

Table 2: Overall effects of LHD on donor return

Version A		
Dependent variable: Probability of making at least one donation attempt within the next 18 months	Female	Male
Mean (dependent variable):	0.655	0.717
LHD	-0.0342 (0.0238)	-0.0607* (0.0364)
Hb	-0.000931*** (0.000243)	-0.000693*** (0.000184)
Hb × D	0.00177 (0.00367)	0.00691 (0.00553)
Age	-0.0410*** (0.00431)	0.0367*** (0.00360)
Age^2	0.00125*** (0.000106)	-0.000440*** (8.53e-05)
Age^3	-1.03e-05*** (8.28e-07)	1.38e-06** (6.38e-07)
R-squared	0.052	0.084
Version B		
Dependent variable: Number of donation attempts within the next 18 months	Female	Male
Mean (dependent variable):	1.200	1.442
LHD	0.00884 (0.0570)	-0.221** (0.0977)
Hb	-0.00145** (0.000677)	-0.00226*** (0.000629)
Hb × D	0.0161* (0.00849)	0.0106 (0.0148)
Age	-0.0939*** (0.0155)	0.0662*** (0.0137)
Age^2	0.00295*** (0.000395)	-0.000424 (0.000341)
Age^3	-2.43e-05*** (3.17e-06)	-1.50e-06 (2.65e-06)
R-squared	0.066	0.090
F-tests of instrument	6047.41	1190.67
Observations	72,025	101,650

Legend: The effects of LHD on donor return are estimated using a linear probability model by 2SLS (for more detail, see Equations A.2 and A.3 in the Supporting Information). In panel A, the outcome variable is the probability of making at least one donation attempt, and in panel B, the outcome variable is the number of donation attempts within the next 18 months. Column 1 shows the analysis for female donors while column 2 shows the analysis for male donors. All regressions additionally include 53 month fixed effects and control for blood types. Individual cluster robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

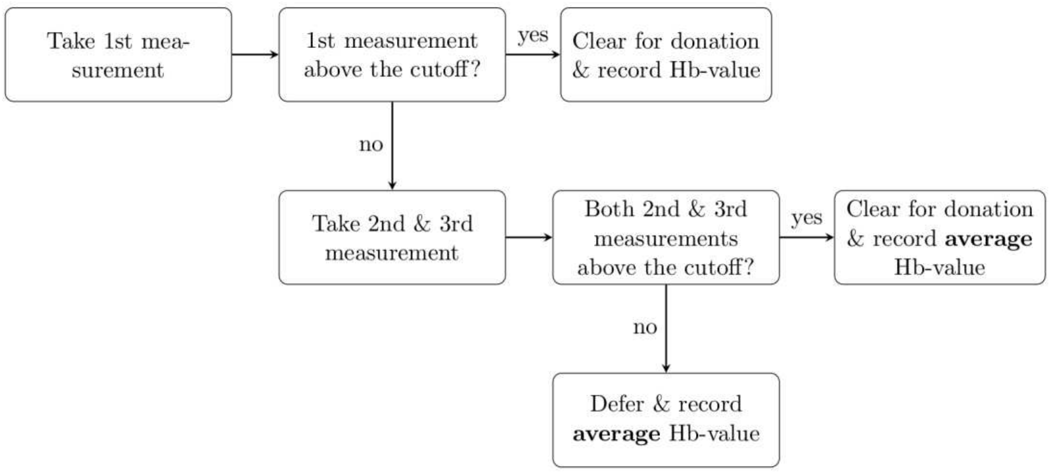
Table 3: Causal effect of repeated LHDs on donor return

Version A		
Dependent variable: Probability of making at least one donation attempt within the next 18 months	Female	Male
Mean (dependent variable):	0.655	0.717
LHD	-0.0216 (0.0237)	-0.0532 (0.0360)
LHD × Past LHD	-0.135*** (0.0288)	-0.133*** (0.0463)
Past LHD	0.120*** (0.00774)	0.0798*** (0.00891)
Hb value	-0.000471* (0.000244)	-0.000526*** (0.000185)
Hb × D	0.00131 (0.00371)	0.00614 (0.00560)
Age	-0.0415*** (0.00427)	0.0365*** (0.00359)
Age^2	0.00126*** (0.000105)	-0.000436*** (8.51e-05)
Age^3	-1.03e-05*** (8.18e-07)	1.35e-06** (6.37e-07)
R-squared	0.055	0.084
LHD+LHD× Past LHD=0	2.30e-05	0.00179
Version B		
Dependent variable: Number of donation attempts within the next 18 months	Female	Male
Mean (dependent variable):	1.200	1.442
LHD	0.0430 (0.0568)	-0.227** (0.0955)
LHD × Past LHD	-0.387*** (0.0738)	-0.152 (0.149)
Past LHD	0.411*** (0.0336)	0.336*** (0.0495)
Hb value	0.000126 (0.000670)	-0.00156** (0.000622)
Hb × D	0.0150* (0.00857)	0.0112 (0.0150)
Age	-0.0956*** (0.0153)	0.0654*** (0.0136)
Age^2	0.00297*** (0.000389)	-0.000409 (0.000338)
Age^3	-2.44e-05*** (3.12e-06)	-1.63e-06 (2.63e-06)
R-squared	0.073	0.092
LHD+LHD× Past LHD=0	0.000184	0.0346
F-tests of instrument	1826.76	573.80
Observations	72,025	101,650

Legend: The effects of repeated LHDs on donor return are estimated using a linear probability model by 2SLS (see Equations A.4 and A.6 in the Supporting Information). In panel A, the outcome variable is the probability of making at least one donation attempt, and in panel B, the outcome variable is the number of donation attempts within the next 18 months. Column 1 shows the20 analysis for female donors while column 2 shows the analysis for male donors. All regressions additionally include 53 month fixed effects and control for blood types. Individual cluster robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

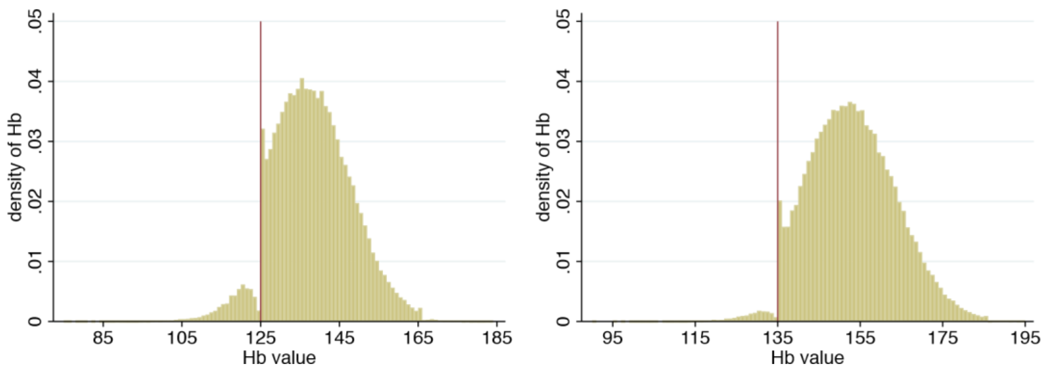
Figures

Figure 1: Procedure of the BTSRC for measuring and recording Hb values.



Legend: To reduce the rate of false LHDs, the BTSRC applies a specific procedure for recording Hb values. When the first measured Hb value is above the cutoff, the staff records that value and clears the individual for donation. However, when the first measurement falls below the cutoff, the staff repeats the measurement twice and records the average Hb value over all three measurements. Only if the final two measurements are both above the cutoff, the staff clears the individual for donation.

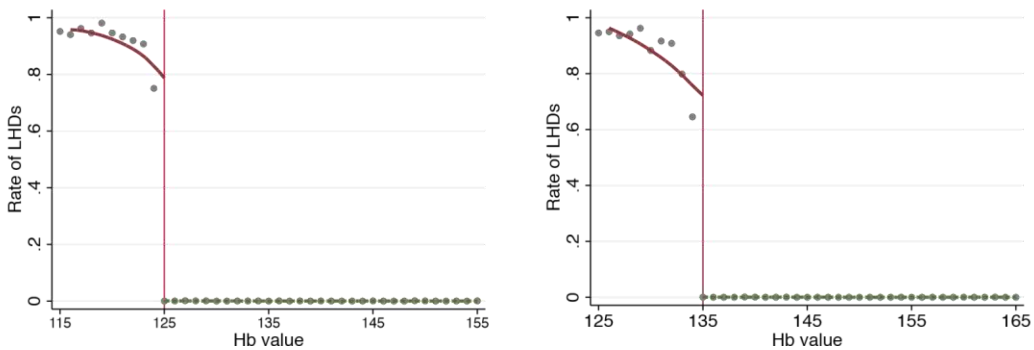
Figure 2: Distribution of recorded Hb values (g/L)



(a) female (b) male

Legend: The normal distribution of the recorded Hb values at the cutoff are distorted because Hb values just below the cutoff are more likely to be revised (see Figure 1 and Table 1). However, since the distortion originates directly from the BTSRC's procedure and not from the donors' behavior, it is uncorrelated with donor return. Thus, LHDs around the cutoff are exogenous with respect to donor return.

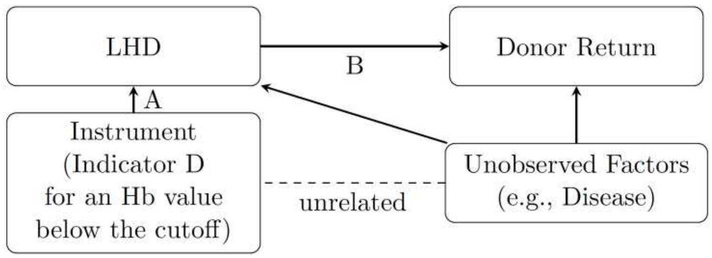
Figure 3: Rate of LHDs at each recorded Hb measurement



(a) Female (b) Male

Legend: For female donors the cutoff is Hb < 125g/L and for male donors it is Hb < 135g/L. The rate of donors experiencing a LHD jumps discontinuously at the cutoff: Donors do not experience any LHDs when their Hb value is above the cutoff but this rate increases discontinuously once their Hb value falls below the cutoff.

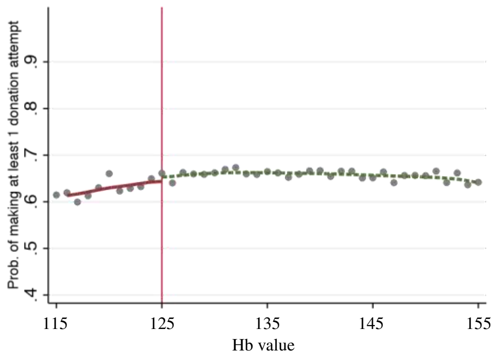
Figure 4: Empirical strategy using an instrument to quantify the causal effect of LHDs on donor return



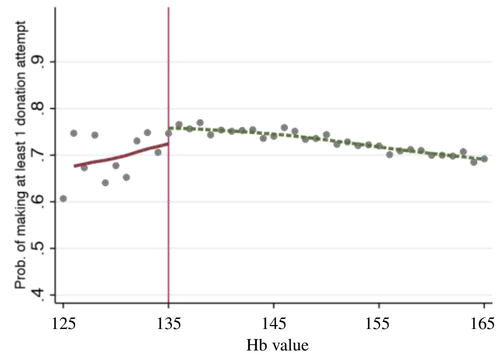
Legend: The indicator D whether a donor's Hb value is below the cutoff serves as an instrument for quantifying the effect of LHDs on the donor's return. The indicator D satisfies two properties, making it a strong and valid instrument. First, D has a strong effect on the probability of experiencing a LHD (see Figure 5). Second, at the margin, D is exogenous with respect to all other unobserved factors that may be related to both, the probability of experiencing a LHD and the donor's return rate. Hence, the variation in LHDs caused by D is exogenous with respect to all unobserved factors (Arrow A) and can be used to quantify the causal effect of LHDs on donor return (Arrow B).

Figure 5: Donor return by Hb measurement

Panel A: Probability of making at least one donation attempt over the next 18 months at each recorded Hb measurement

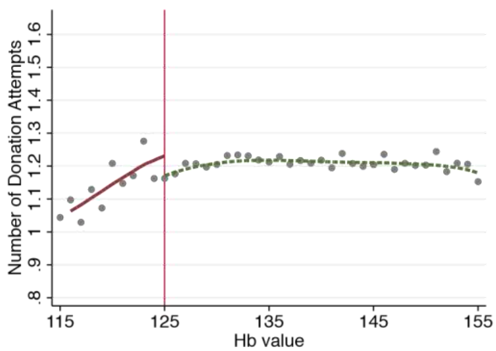


(a) Female

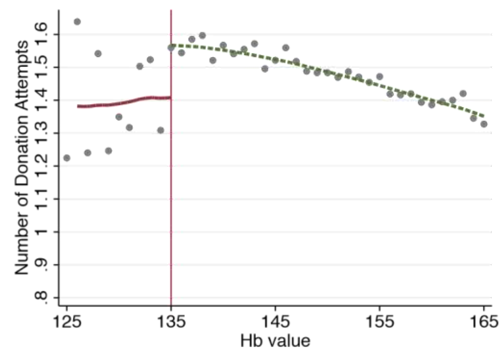


(b) Male

Panel B: Number of donation attempts over the next 18 months at each recorded Hb measurement



(a) Female



(b) Male

Legend: The red and green lines are based on local linear regressions. The dots represent the mean probabilities (Panel A) and numbers (Panel B) by Hb value.